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著者	TERAOKA TAKASHI
journal or publication title	Tohoku psychologica folia
volume	37
page range	131-144
year	1979-03-20
URL	http://hdl.handle.net/10097/00064916

Tohoku Psychologica Folia
1978, 37(1-4), 131-144

EFFECTS OF COALITION IN THE SYMMETRIC THREE-PERSON NON-ZERO SUM MATRIX GAME

—— SIMULATION ANALYSIS OF THE SELECTION PROCESSES BASED UPON THE NORMATIVE MODELS OF NEEDS WITH REFERENCE TO THE MARTYR SITUATION ——

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The 6 normative models of *need for coalition* among players in the *symmetric 3-person non-zero sum games of the* $2\times2\times2$ *type* were constructed. The processes of response selection based on all the possible *needs systems* which are combinations of 3 needs were simulated by a computer for the 13 *martyr games*. The main results of the simulation were as follows. i) It was possible to realize the *mutual prosperity cell* as the terminal state by the needs systems consisting of only the *joint gains needs* among 2 players even under the *PD game* situation. ii) It was suggested that the PD in 3-person games should be divided into the *weak* and the *strong types* depending on the logical structure of the matrix.

Introduction

The problem of *coalition* constitutes generally one of the most fundamental aspects in the theoretical description of the structure of human relations in the n-person game situation. The coalition among players in the three-person game is the basic forms of the coalition in the n-person game. According to the traditional theories of coalition (for example, Caplow, 1968), it has been pointed out that any form of coalition may be formed when the structure of the power or the payoff condition in the three-person game is *symmetric* among the players. It seems understandable, therefore, that the traditional theories have placed a more accent on the complex problems in coalition formation where the relation among the three players is *non-symmetric*. However, some novel facts might be found even in such a simple symmetric situation if it is possible to assume that some hierarchical structure exists between the given game situation and some superordinate situation as dominating the former.

The principal purposes of this paper are to put forward the *assumption of some hierarchical structure between situations*, and to construct the normative models of the needs for coalition among players in the *symmetric three-person non-zero sum games* represented by a payoff matrix of the $2\times2\times2$ type on that assumption, and moreover,

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to clarify logically the structural properties based upon the coalition in the fundamental dilemma game called the *martyr in three-person games* by analyzing the selection processes derived from the models of needs by means of computer simulation.

The Hierarchical Structure Between Situations

The following assumption was adopted in order to rationalize the present attempt to construct the models of needs for coalition and to analyze the processes of selecting responses derived from the models. The assumption can be expressed in the following four statements: i) some superordinate situation exists over the given game situation, ii) the form of characteristic function for the superordinate situation is generally disregarded for the time being, but, iii) the direction concerning the coalition among the three players under the given game situation is firmly controlled by that superordinate situation, and, iv) the form of characteristic function for the superordinate situation is never affected by the processes of response selection under the present game situation.

This assumption means that each player is obliged to select his responses depending on the structure of the coalition already firmly determined by the superordinate situation which exists implicitly but which controls the given matrix game situation; in other words, the structure of coalition among three players in the present game situation is given independently of the structure of matrix and the processes of selecting responses under the game situation are rather perfectly dependent upon the already determined structure of coalition. This makes ours a contrasting point of departure from that of the traditional theories. Thus we can have the logical basis of analyses on the relations between the processes of response selection and the various clearly represented coalitions.

Needs System

Let us suppose that the behavior of each player $P_\lambda=(\lambda=1,2,3)$, in the three-person game, is controlled by two fundamental motives which specify the criterion of selecting responses, that is, the *associative motives* and the *purposive motives*. The associative motives concern the size of *association* which means the form of coalition among players in the traditional term. These are further divided into three submotives, *viz.*, the *individual motive*, the *coalition motive* and the *solidarity motive* as shown in Table 1. The purposive motives concern the so-called social motivations or the purpose of selecting responses. These are further divided into two submotives, *viz.*, the *score motive* and the *difference motive.*

The player with the *individual motive* as one of associative motives is never inclined to form any association. The player P_λ with the *coalition motive* is inclined to choose either of the players, $P_{\lambda'}$ and $P_{\lambda''}$ as his partner, though the player's one-sided choice of the partner does not always mean that the real coalition is formed between the two players. The player with the *solidarity motive* is inclined to choose both the other two players as his partners. The player with the *score motive* as one of purposive motives

Table 1. Needs as combinations of the associative motives and the purposive motives.

Associative motives	Purposive motives	
	Score motive	Difference motive
Individual motive	Individual profit need $M_{\lambda}(\lambda;S)$ ▲	Single domination need $M_{\lambda}(\lambda;D)$ △
Coalition motive	Joint gains need $M_{\lambda}(\lambda,\lambda';S)$ $M_{\lambda}(\lambda,\lambda'';S)$ ■→	Expulsive clique need $M_{\lambda}(\lambda,\lambda';D)$ $M_{\lambda}(\lambda,\lambda'';D)$ □→
Solidarity motive	Common property need $M_{\lambda}(\lambda,\lambda',\lambda'';S)$ ←●→	Entire equalization need $M_{\lambda}(\lambda,\lambda',\lambda'';D)$ ←○→

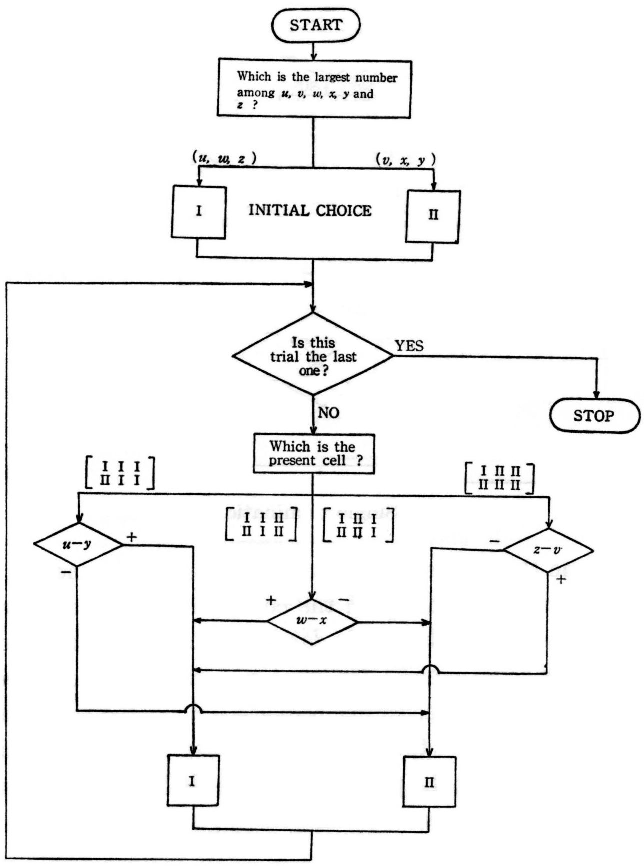

Fig. 1. Individual profit need.

is inclined to make the total gains of his own association as large as possible, and the player with the *difference motive* is inclined to make the difference between the score level of his own association and the score level of the other group or player as large as possible.

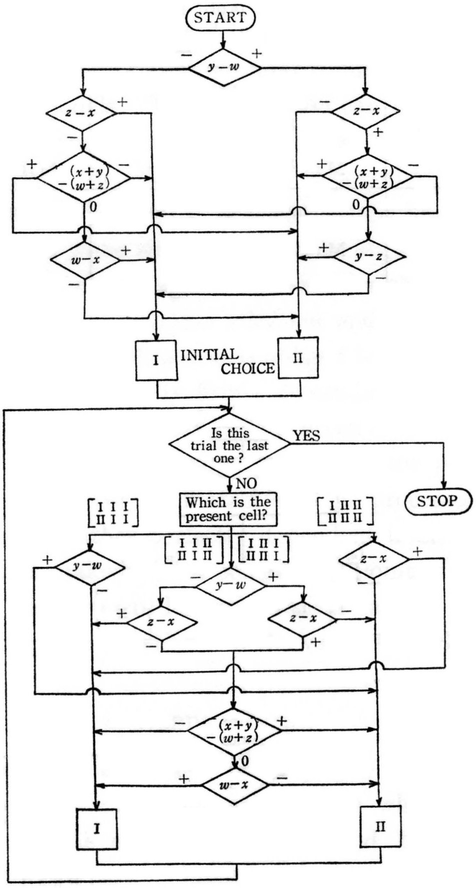

Fig. 2. Single domination need.

Next, let us assume that the combination of an associative motive and a purposive motive constructs a *need*. For examples, the combination of the individal motive and the difference motive constructs the *single domination need* and the combination of the coalition motive and the score motive the *joint gains need*. Each need in each player specifies the concrete criterion in selecting responses along the sequence of trials under the given game situation. Thus a total of six needs obtain as the normative models, but each player can have one among the possible eight needs because the two needs based on the coalition motive, the *joint gains need* and the *expulsive clique need*, are divided into two sorts, respectively.

The algorithms of selections based upon these needs were shown in Fig. 1–Fig. 6.

In drawing these figures, a few additional criterions were introduced. Anyway each player can choose a need from among the eight ones independently of the other two players. Therefore, the number of all the possible combinations in the eight needs among three players is 104 as shown in Table 2. The arrows in the figure indicate the direction in the player's associative motive. The combination of the three needs among the three players is called the *needs system.*

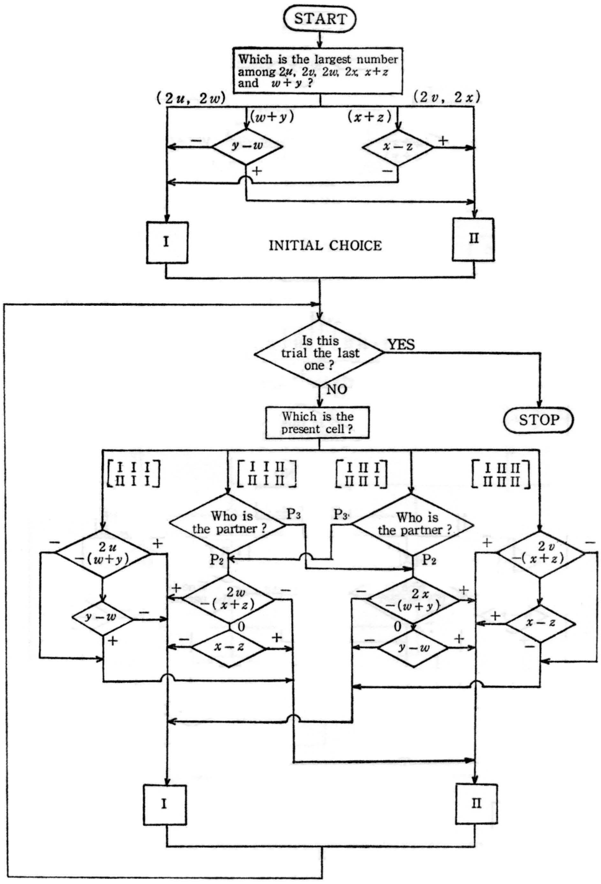

Fig. 3. Joint gains need.

The Martyr in Three-Person Games

The game used in the present study is called the *martyr with four score levels in three-person games*. Teraoka (1978) has divided the symmetric three-person non-zero sum matrix games into four main classes both with regards to the *fixed* and the *non-fixed types* and with regards to the *standard* and the *degenerative types*. According to his classification, the above martyr game belongs to a group of the games of the *fixed degenerative type* because the number of maximum possible score levels is six in the games of the standard type. Accordingly, the game used in the present paper might be, in a sense, the martyr of a special form. However, the inspection of the game of this type would be rather useful for comparing it with the martyr in two-person games and for analyzing the essential characteristics of martyr games, because the number of martyr games is only one in the three-person games with four score levels as shown in Table 3b in contrast to the ten types in the standard games with six score levels.

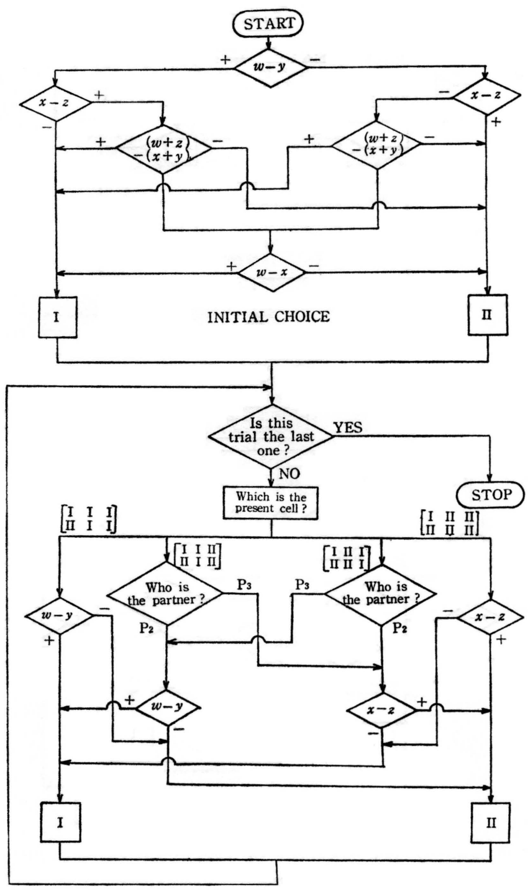

Fig. 4. Expulsive clique need.

When some needs system containing the *joint gains need* or the *common property need* is formed under a game situation, the selection processes of the players depends on the sum of scores of the two or three players or on the difference between the sum of scores of the two players and that of the remaining player in a cell of the payoff matrix. Therefore, the various payoff matrices represented by the actual scores of some specific values, not by score levels, should be treated as the objects for analyses, even though the matrix represented by the score levels in this paper is only one. As shown in Table 4, we can prepare a set of thirteen matrices (T01–T13) possessing as a whole all the possible essential structures in the martyr with four score levels. All of these matrices were used for the following simulation.

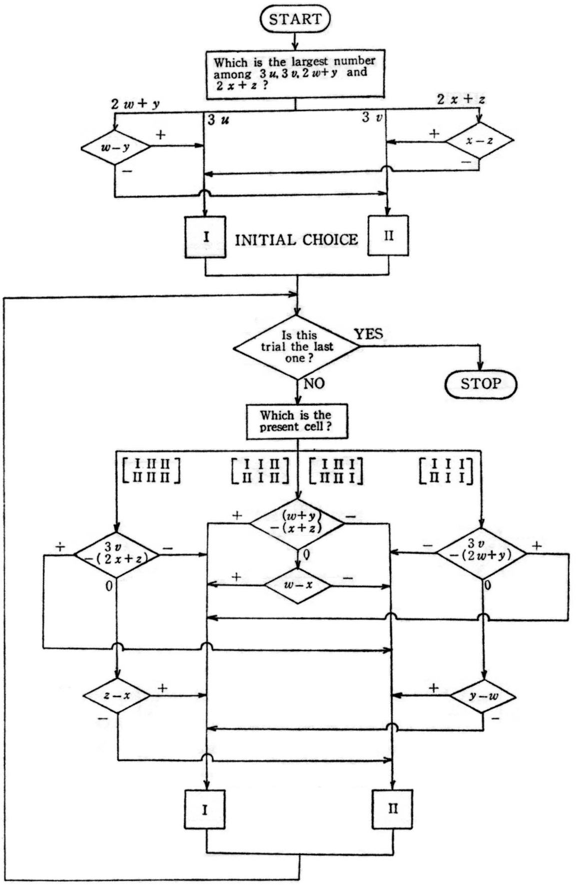

Fig. 5. Common property need.

RESULTS OF COMPUTER SIMULATION

Table 5 shows the terminal states in the processes of selecting responses for each of the thirteen matrix games based upon the 104 needs systems. These were the results simulated by a computer*. The thirteen matrices are ultimately classified into five groups as shown in Table 5, *viz.* Group **I** (T01–T02), Group **II** (T03), Group **III** (T04–T05), Group **IV** (T06–T12) and Group **V** (T13). The perfectly same results were obtained for the matrix games contained in a group. This classification is based upon the form of absorption and circulation in the terminal states. The absorption is divided

* The computer, FACOM 630–75, in Hokkaido University Computing Center was used for this simulation research.

into four cases, *viz.*, the case of absorption into the cell {I I I} (sign S in the table), the cells {II II III} (S′), {I I II} (D) and {I II II} (D′). The cells {I I I} and {II II II} mean (B B B) and (C C C), respectively, where these cells are indicated by the levels of score. The cell {I I II} as a category in the raw or the column on this table contains really the cases {I I II}, {I II I} or {II I I} as the initial or terminal states. Anyway the signs S, S′, D and D′ in the table mean the respective forms of absorption in the terminal states. Sign C_n means a circulation among n cells.

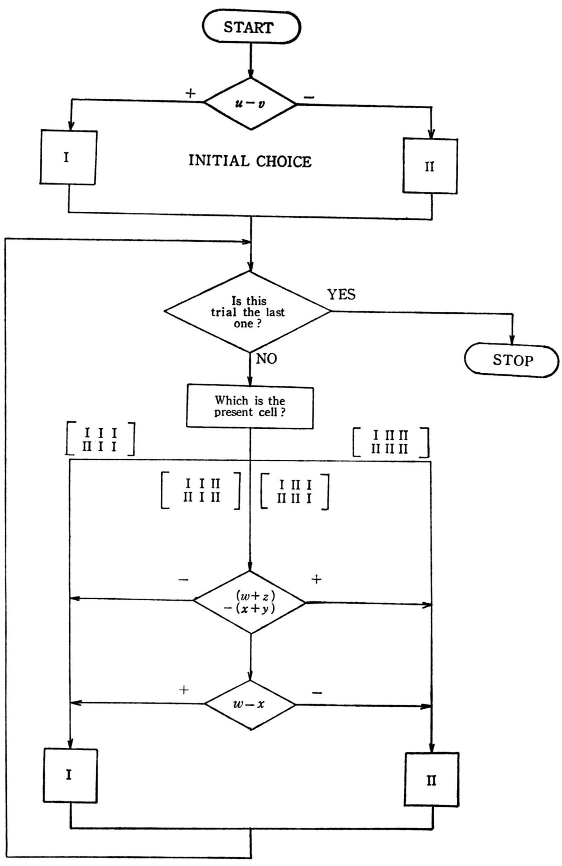

Fig. 6. Entire equalization need.

Table 6 shows various total numbers concerning the terminal states for the thirteen matrix games on the basis of the 104 needs systems. The numbers in the table mean the frequencies of the needs systems. Notice that the number of absorption into the cell {II II II} is fairly larger for the processes in the two matrix games contained in the Group **I**, T01 and T02, than for the processes in the other matrix games.

Next, let us focus on the results for the so-called *prisoner's dilemma games* as a special case of the martyr among three-person games. These prisoner's dilemma games are T01,

Table 2. All the possible needs systems as combinations of three needs among the players.

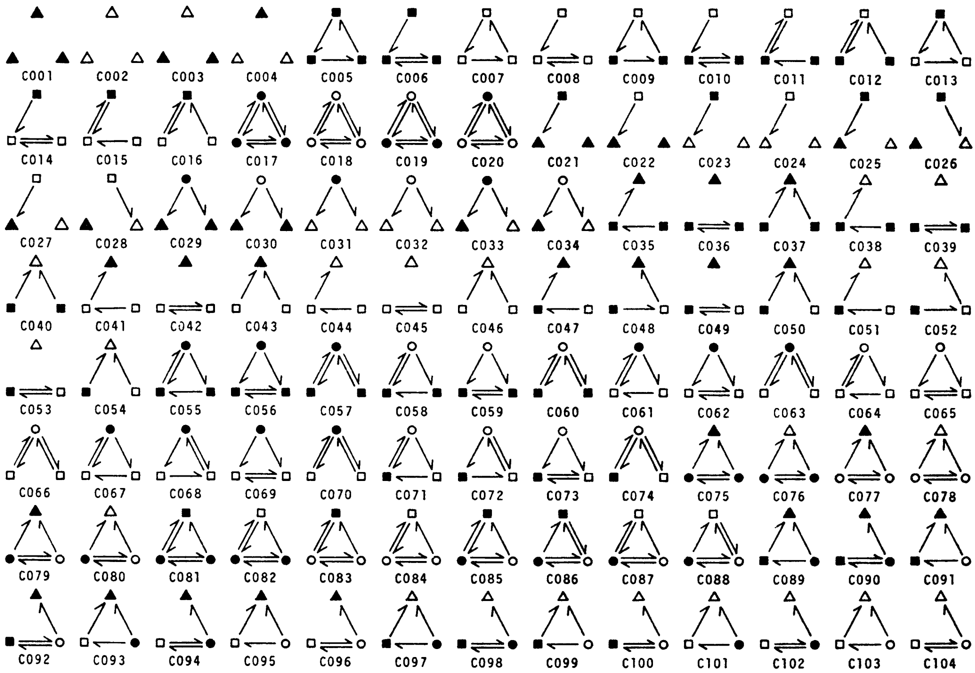

Table 3. Payoff matrix with a general form in the three-person non-zero sum games and the matrix of martyr game of a degenerative type used in the analysis.

		(a)		(b)	
		P_2		P_2	
P_1	P_3	I	II	I	II
I	I	*uuu*	*wyw*	*BBB*	*DAD*
	II	*wwy*	*zxx*	*DDA*	*DAA*
II	I	*yww*	*xxz*	*ADD*	*AAD*
	II	*xzx*	*vvv*	*ADA*	*CCC*
		$w=z$ and $y=x$		$A>B>C>D$	

T02 and T05 and they belong to either Group I or Group III. It was found already in Table 5 and 6 that the number of the needs systems introducing the response selection into the so-called mutual prosperity cell {I I I} as the terminal cell is four in the Group I and six in the Group III. These six needs systems were C005, C006, C017, C018, C019 and C020 as easily grasped from the results in Table 5. Notice that the four common needs systems consist of only needs based on the solidarity motives among the

Table 4. Possible matrices of the martry game with four levels.

T01	T02	T03	T04	T05
$2C>A+D$	$2C=A+D$	$2B>A+D>2C$ $3C>A+2D$	$3C=A+2D$	$3C<A+2D$
4 4 4 0 5 0 0 0 5 0 5 5 5 0 0 5 5 0 5 0 5 3 3 3	3 3 3 0 4 0 0 0 4 0 4 4 4 0 0 4 4 0 4 0 4 2 2 2	3 3 3 0 5 0 0 0 5 0 5 5 5 0 0 5 5 0 5 0 5 2 2 2	2 2 2 0 3 0 0 0 3 0 3 3 3 0 0 3 3 0 3 0 3 1 1 1	3 3 3 0 4 0 0 0 4 0 4 4 4 0 0 4 4 0 4 0 4 1 1 1
T06	**T07**	**T08**	**T09**	**T10**
$2B=A+D$ $3C>A+2D$	$2B=A+D$ $3C=A+2D$	$2B=A+D$ $3C<A+2D$	$2B<A+D$ $3C>A+2D$	$2B<A+D$ $3C=A+2D$
4 4 4 0 8 0 0 0 8 0 8 8 8 0 0 8 8 0 8 0 8 0 3 3	3 3 3 0 6 0 0 0 6 0 6 6 6 0 0 6 6 0 6 0 6 2 2 2	2 2 2 0 4 0 0 0 4 0 4 4 4 0 0 4 4 0 4 0 4 1 1 1	5 5 5 0 11 0 0 0 11 0 11 11 11 0 0 11 11 0 11 0 11 4 4 4	4 4 4 0 9 0 0 0 9 0 9 9 9 0 0 9 9 0 9 0 9 3 3 3
T11	**T12**	**T13**		
$2B<A+D$ $3B>A+2D>3C$	$3B=A+2D>3C$	$3B<A+2D$		
2 2 2 0 5 0 0 0 5 0 5 5 5 0 0 5 5 0 5 0 5 1 1 1	2 2 2 0 6 0 0 0 6 0 6 6 6 0 0 6 6 0 6 0 6 1 1 1	2 2 2 0 7 0 0 0 7 0 7 7 7 0 0 7 7 0 7 0 7 1 1 1		

three players as shown in Table 2. In other words, even the needs systems consisting of only the joint gains needs among three players, C005 and C006, can lead into {I I I} in the prisoner's dilemma with the structure of the matrix T05. Moreover, these results emphasize that the needs systems containing one or more needs based upon the individual motive can never lead into {I I I} as the terminal state in any martyr game.

However, these results were essentially based on the algorithms of the need models as shown in the Figures. The mechanisms of choices based on these need models contains such additional criterions as the following: namely, i) at the first trial, the player tries to choose the cell among the eight cells in the matrix matching optimally to his present need independently of the intentions of the other two players, ii) when it is difficult to decide between the alternatives according to the basic structure of each need, the player chooses it by adopting the new criterion based upon the motive opposite to his present motive, for example, the *single domination need* as opposed to the *individual profit need*, and, iii) the selection of alternative in the next trial for a player is always based on the assumption that the other two players would not change the alternatives which they has already chosen at the present trial.

A set of these assumptions is introduced as a primary approximation for the mechanism of choices under game situations. If the initial choices among the players are different from the ones based on these models, it is supposed at least that the form

Table 5. Terminal states of selection processes for the thirteen matrices of the martyr game with four levels.*

Needs system	Group of matrices					Needs system	Group of matricas				
	I	II	III	IV	V		I	II	III	IV	V
001	S′	S′	S′	S′	S′	053	S′	D′	D′	D′	D′
002	S′	S′	S′	S′	S′	054	S′	D′	D′	D′	D′
003	S′	S′	S′	S′	S′	055	D′	S	D′	D′	C2
004	S′	S′	S′	S′	S′	056	D′	S	D′	D′	C2
005	S′	S	S	C2	C2	057	D′	S	D′	D′	C2
006	S′	S	S	C2	C2	058	S′	C3	C3	C3	C3
007	S′	S′	S′	S′	S′	059	S′	C3	C3	C3	C3
008	S′	S′	S′	S′	S′	060	S′	C3	C3	C3	C3
009	S′	C2	C2	C2	C2	061	D′	D′	D′	D′	D′
010	S′	C2	C2	C2	C2	062	D′	D′	D′	D′	D′
011	S′	C2	C2	C2	C2	063	D′	D′	D′	D′	D′
012	S′	C2	C2	C2	C2	064	S′	S′	S′	S′	S′
013	S′	D′	D′	D′	D′	065	S′	S′	S′	S′	S′
014	S′	D′	D′	D′	D′	066	S′	S,	S′	S′	S′
015	S′	D′	D′	D′	D′	067	D′	C2	D′	C2	C2
016	S′	D′	D′	D′	D′	068	D′	C2	D′	C2	C2
017	S	S	S	S	C2	069	D′	C2	D′	C2	C2
018	S	S	S	S	S	070	D′	C2	D′	C2	C2
019	S	C3	S	C3	C3	071	S′	D′	D′	D′	D′
020	S	D′	S	D′	D′	072	S′	D′	D′	D′	D′
021	S′	D′	D′	D′	D′	073	S′	D′	D′	D′	D′
022	S′	D′	D′	D′	D′	074	S′	D′	D′	D′	D′
023	S′	D′	D′	D′	D′	075	D	C2	C2	C2	C2
024	S′	D′	D′	D′	D′	076	D	C2	C2	C2	C2
025	S′	D′	D′	D′	D′	077	S′	S′	S′	S′	S′
026	S′	D′	D′	D′	D′	078	S′	S′	S′	S′	S′
027	S′	S′	S′	S′	S′	079	D′	D′	D′	D′	D′
028	S′	S′	S′	S′	S′	080	D′	D′	D′	D′	D′
029	D′	D′	D′	D′	D′	081	D	S	D′	C3	C2
030	S′	S′	S′	S′	S′	082	D	C2	C2	C2	C2
031	D′	D′	D′	D′	D′	083	S′	D′	D′	D′	D′
032	S′	S′	S′	S′	S′	084	S′	S′	S′	S′	S′
033	D′	D′	D′	D′	D′	085	D′	C3	D′	C3	C3
034	S′	S′	S′	S′	S′	086	D′	C3	D′	C3	C3
035	S′	C2	C2	C2	C2	087	D′	C3	D′	D′	D′
036	S′	C2	C2	C2	C2	088	D′	D′	D′	D′	D′
037	S′	C2	C2	C2	C2	089	D′	C2	D′	C2	C2
038	S′	C2	C2	C2	C2	090	D′	C2	D′	C2	C2
039	S′	C2	C2	C2	C2	091	S′	D′	D′	D′	D′
040	S′	C2	C2	C2	C2	092	S′	D′	D′	D′	D′
041	S′	S′	S′	S′	S′	093	D′	D′	D′	D′	D′
042	S′	S′	S′	S′	S′	094	D′	D′	D′	D′	D′
043	S′	S′	S′	S′	S′	095	S′	S′	S′	S′	S′
044	S′	S′	S′	S′	S′	096	S′	S′	S′	S′	S′
045	S′	S′	S′	S′	S′	097	D′	C2	D′	C2	C2
046	S′	S′	S′	S′	S′	098	D′	C2	D′	C2	C2
047	S′	D′	D′	D′	D′	099	S′	D′	D′	D′	D′
048	S′	D′	D′	D′	D′	100	S′	D′	D′	D′	D′
049	S′	D′	D′	D′	D′	101	D′	D′	D′	D′	D′
050	S′	D′	D′	D′	D′	102	D′	D′	D′	D′	D′
051	S′	D′	D′	D′	D′	103	S′	S′	S′	S′	S′
052	S′	D′	D′	D′	D′	104	S′	S′	S′	S′	S′

* Group I means the set of matrices T01–T02. Group II contains only T03, Group III T04–T05, Group IV T06–T12 and Group V only T13. S means the cell {I I I} in the matrix. S′, D and D′ means {II II, II}, {I I II}, and {I II II}, respectively. C_n means a circulation among n cells.

Table 6. The distribution of absorption and circulation in the selection processes for the thriteen matrices of the martyr game with four levels.

Initial choice		Absorption									Circulation				
		Cell				Trial				Total	Length		Trial		Total
		{I I I} ·· {II II II}				1	2	3	4		2	3	1	2	
(T01–T02)															
{I I I}	4	4	0	0	0	4	0	0	0	4	0	0	0	0	0
{I I II}	14	0	0	6	4	0	3	5	2	10	3	1	4	0	4
{I II II}	42	0	0	21	21	21	21	0	0	42	0	0	0	0	0
{II II II}	44	0	0	0	44	44	0	0	0	44	0	0	0	0	0
Total	104	4	0	27	69	69	24	5	2	100	3	1	4	0	4
(T03)															
{I I I}	1	1	0	0	0	1	0	0	0	1	0	0	0	0	0
{I I II}	5	0	0	2	3	0	5	0	0	5	0	0	0	0	0
{I II II}	28	0	0	10	12	0	12	10	0	22	0	6	6	0	6
{II II II}	70	7	0	28	14	14	35	0	0	49	21	0	21	0	21
Total	104	8	0	40	29	15	52	10	0	77	21	6	27	0	27
(T04–T05)															
{I I I}	4	4	0	0	0	4	0	0	0	4	0	0	0	0	0
{I I II}	14	0	0	8	3	0	7	4	0	11	3	0	3	0	3
{I II II}	42	0	0	29	10	21	10	8	0	39	0	3	3	0	3
}II II II}	44	2	0	18	14	14	20	0	0	34	10	0	10	0	10
Total	104	6	0	55	27	39	37	12	0	88	13	3	16	0	16
(T06–T12)															
{I I I}	1	1	0	0	0	1	0	0	0	1	0	0	0	0	0
{I I II}	5	0	0	2	3	0	4	1	0	5	0	0	0	0	0
{I II II}	28	0	0	12	10	0	10	12	0	22	0	6	6	0	6
{II II II}	70	1	0	31	14	14	29	3	0	46	23	1	24	0	24
Total	104	2	0	45	27	15	43	16	0	74	23	7	30	0	30
(T13)															
{I I I}	1	1	0	0	0	1	0	0	0	1	0	0	0	0	0
{I I II}	5	0	0	2	3	0	3	2	0	5	0	0	0	0	0
{I II II}	28	0	0	12	10	0	10	12	0	22	0	6	6	0	6
{II II II}	70	0	0	28	14	14	28	0	0	42	28	0	28	0	28
Total	104	1	0	42	27	15	41	14	0	70	28	6	34	0	34

in the terminal states might also be different from the results as shown in Table 5 and 6. Now, let us concentrate on the results for the games with the prisoner's dilemma type among three players, which were T01, T02 and T05, because it seems that the games of this type have the structure of the most important dilemma in the martyr games.

The number of all possible states of the initial choices in a matrix game is eight. The structures of the terminal states in the above three games were inspected thoroughly in every one of the eight states of initial choices and in every one of the 104 needs systems by the computer simulation. From this analysis, it was clarified that the

16 needs systems as shown in Table 7 have possibilities to lead into {I I I}, provided that the cell of the initial choices is adequate. In Table 7, Type **A** means that {I I I} is realized as the terminal cell when the initial cell is {I I I} or {II II II}. When the initial cell is either {I I II} or {I II II}, {I II II} is always realized as the terminal cell for all 16 needs systems. Both Type **B** and Type **C** mean that the {I I I} is realized as the terminal cell only when the initial cell is {I I I}. When {I I I} is not realized as the initial cell, the terminal cell is always {I II II} in Type **B** and {II II II} in Type **C**. In Table 7, the number of **A** is larger in the Group **III** and the number of **C** larger in the Group **I**. Therefore, it seems that the matrices contained in Group **I**, T01 and T02, represent 'harsher' dilemma situations than the matrix in Group **III**, T05, as to the realization of {I I I} as the terminal state. In other words, the prisoner's dilemma in three-person games, which has the structure of $3B>2A+D$ as to the score levels, is at least divided into two types, *viz.*, the *weak* and the *strong types*, depending on the logical structure. The conditions of the weak and the strong types in the prisoner's dilemma are that $3C\leqq A+2D$ for the former and $2C\geqq A+D$ for the latter on the matrix of Table 3b.

Table 7. Sixteen needs systems in which {I I I} is possible to appear as th terminal stage for the prisoner's dilemma in the three-person games.*

Needs system	5	6	17	18	19	20	55	56	57	58	59	60	81	83	85	86
T01 & T02	C	C	A	C	B	B	B	B	B	C	C	C	B	C	B	B
T04 & T05	A	A	A	C	B	B	A	A	A	B	B	B	A	B	B	B

* **A**, **B** and **C** are the names of type. For example, Type **A** means that {I I I} is realized as the terminal cell when the initial cell is {I I I} or {II II II}.

Next, let us take a glance at the relation between the needs systems and the strong or weak structures of these matrices. From the results shown in Table 7, it is pointed out that the two needs systems with three joint gains needs, C005 and C006, have a potential power to realize the cell {I I I} as the terminal state even when the players drop down into {II II II}, at least, for the matrix T05 of the weak type. On the other hand, any needs systems containing even one *entire equalization need* has no potentiality such as mentioned above when the players drop down into {II II II}. Though these results, of course, would depend upon the sorts of models, it seems that some interesting suggestions concerning the social motivation or the association among persons are contained in the results.

Conclusion

The first purpose of the present study was to construct the normative models of the needs for association among the players in the symmetric threeperson non-zero sum matrix games of the $2\times2\times2$ type. The second purpose was to clarify the structural properties of the martyr game, particularly the prisoner's dilemma in the three-person games, based upon the above needs models by computer simulation research. The main results of some importance in the simulation research were as follows. i) As long as the cell of the initial choices among the three players happen to be adequate, the *mutual prosperity cell* {I I I} can be realized as the terminal state in the processes of selecting responses under the prisoner's dilemma situation by the needs systems constituting of only the joint gains needs among two players even though they are not based upon any solidarity motives. ii) It was suggested that the prisoner's dilemma in three-person games could be divided into several types, but as long as the need models presented in this paper were concerned, two types, *viz.*, the weak and the strong types, were found. Generally, both the structure of the score levels in the payoff matrices and the form of needs models would determine the type.

These results may have some limitation because these were based on the simple models of needs as a primary approximation. However, some further such analyses would provide the frame for analyses of the processes of responses selected by real human subjects and would provide the ground for grasping logically the structural properties in the *space of game situations*.

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(Received November 30, 1978)